Craniectomy and orbitectomy in dogs and cats

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Tumors of the cranium and orbit pose diagnostic and therapeutic challenges. With advances in diagnostic imaging, surgical oncology, anesthesia techniques and post-operative ICU care, successful surgical treatment of some of these tumors is possible. On initial examination of the patient with a mass on the skull, this group of tumors can appear quite similar. However, there is a wide range of tumors that can affect the cranium and orbit. These can be divided into tumors of the cranium, orbital and periorbital tumors, and tumors of the soft tissue of the head.

The diagnostic workup for most of these tumors is similar. The workup involves obtaining a definitive tissue diagnosis, staging, and advanced imaging. Staging of the mass should involve 3-view thoracic radiographs and aspirates of the draining lymph nodes. If the mass is an osteosarcoma (OSA), a thorough orthopedic examination and bone scan should be performed to rule out metastatic disease and/or a primary OSA elsewhere. An incisional biopsy should be performed to obtain a histologic diagnosis when possible. A fine-needle aspiration (FNA) biopsy for cytology is an appropriate initial step in making a diagnosis. However, because of the morbidity involved in an orbitectomy or craniectomy, it is preferable to have a histopathologic diagnosis prior to definitive surgical treatment. Prior to definitive surgical treatment, three-dimensional (3-D) imaging with either computed tomography (CT) or magnetic resonance imaging (MRI) should be performed for surgical planning. The decision to perform a CT or MRI will depend on machine availability, suspected diagnosis, and the surgeon's preference. A CT scan is faster, often less expensive, useful for neoplastic processes involving bone, and can be used to reassess the lungs for metastatic disease during the same scan. If radiation is available, the CT can be performed as a diagnostic and radiation-planning CT. This is useful for cases in which surgical treatment is not possible due to advanced disease, where radiation therapy may be the next best option. A CT scan of the thorax and skull, including draining lymph nodes, followed by an incisional biopsy of the mass will yield a great deal of preoperative information to the surgeon. Magnetic resonance imaging is useful if there is suspect CNS involvement and for primarily soft tissue masses. If done under the same anesthetic, the advanced imaging should be performed prior to biopsy to ensure that hemorrhage/edema caused by the biopsy does not confound the imaging results. Using this information, a definitive surgical treatment can be planned.

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Tumors of the calvarium

Common tumors of the calvarium are primary bone tumors such as osteosarcoma (OSA) and multilobular osteochondrosarcoma (MLO). Other sarcomas such as hemangiosarcoma, fibrosarcoma, anaplastic sarcoma and chondrosarcoma are possible differential diagnoses. Osteosarcoma of the skull appears to have a similar biological and metastatic behavior to appendicular osteosarcoma. Although there is no study that examines cranial/skull OSA specifically, several retrospective studies have evaluated axial skeletal OSAs, with skull OSAs making up a large percentage of these cases (1–3). With the exception of mandibular OSA (3,4), there does not appear to be a survival benefit for axial OSA compared with appendicular OSA. The reported metastatic rates at presentation for axial OSA are 11% to 18% (1–3), with a metastatic rate at presentation for skull OSA of 40% in 1 study (2). The one significant difference of an axial compared to an appendicular location is that death is often due to local disease rather than metastatic disease. Death due to local disease has been reported in 3 retrospective studies on canine axial OSA as 55%, 64%, and 79.6% (1–3). This is primarily because complete excision of an axial OSA is more challenging or may not be possible compared with an appendicular OSA. In the study by Dickerson et al (1), most of the cases were treated with palliative or curative intent radiation. This study found a significant survival benefit in dogs treated with curative intent radiation, rather than palliative radiation (1). Curative intent radiation therapy should be considered in cases where surgical excision is not possible. Stereotactic radiosurgery is a curative intent treatment option for skull osteosarcoma that is becoming increasingly available. This involves 1 to 3 doses of radiation to the tumor, with minimal side effects to surrounding structures. Although there is currently no literature on this treatment technique in dogs with skull tumors, it is likely that this treatment modality will become more common in the future. Treatment of OSA of the skull should be similar to treatment of appendicular OSA. Aggressive local control with curative intent surgery or radiation should be the goal, with adjunctive chemotherapy.

Multilobular osteochondroma or osteochondrosarcoma (MLO) is a primary tumor of the flat bones of the skull.

Clinically, these cases present as a firm, fixed, slow growing mass (5). The typical radiographic and CT appearance of an MLO is that of a "popcorn ball" because of varied nodular mineralized densities within the mass, the multilobular nature of the tumor, and the osteoproductive and osteolytic pattern (5). In Dernell et al's retrospective of 39 cases of canine MLO, the typical presentation was medium and large breed dogs with a median age of 8 y (5). Surgery was the primary treatment in this retrospective study, with either no adjunctive therapy or a varied adjunctive post-operative treatment with radiation and/or chemotherapy. In this study, 47% of the dogs developed local recurrence at a median time of 797 d and 56% developed metastasis (primarily to the lungs); 33% of the cases that developed local recurrence went on to develop metastasis. The median survival time in this report was also 797 d and the median time to death from onset of recurrence or metastasis was 239 d, indicating that these tumors take a slow course (5). Incomplete surgical margins and high histologic grade (grade III) were both found to have a significant effect on decreasing time to local recurrence. Tumor grade also had a significant effect on time to metastasis. Similar to OSA, mandibular sites also had a significantly increased survival time compared with nonmandibular sites (5). Adjunctive treatment with radiation and/or chemotherapy has not been shown to be protective (5). However, this may be a function of the small number of dogs treated with adjunctive therapy and the retrospective nature of this study. As with cranial OSA, MLO treatment should be focused on local control with aggressive surgical excision when possible. The role of adjunctive therapy is not known but chemotherapy should be considered with intermediate or high-grade tumors.

Craniectomy is performed for tumors overlying the calvarium. These may be primary bone tumors such as OSA or MLO or soft tissue tumors that invade or are attached to the bone, such as a soft tissue sarcoma. Primary bone tumors such as OSA and MLO can usually be removed with preservation of the surrounding soft tissues. Bone margins of 1–2 cm should be the goal of excision. The ability of the temporalis muscle to be preserved will depend on whether or not the tumor is growing into it. If it is possible to preserve it, it is useful to reconstruct the defect after the craniectomy. The bone is removed using a Hall's air drill. The CT or MRI should be studied carefully and the surgeon should know whether or not one of the sinuses (the dorsal sagittal and 2 transverse sinuses) will be encountered during surgery. Hemorrhage from these sinuses can be significant and life-threatening. As well, it has been suggested that ligation of 2 of the 3 sinuses will result in cerebral hypertension and brain herniation (6). Experimentally, an acute unilateral transverse sinus occlusion has been performed successfully in dogs with either no or transient neurologic deficits and no increase in intracranial pressure (7). Clinically, acute unilateral transverse sinus occlusion was performed to remove intracranial masses in 7 cases with no apparent ill-effects. This was, however, difficult to determine definitively due to the underlying intracranial disease and type of surgery performed (8). It has also been suggested that the dorsal sagittal sinus can be occluded acutely with no ill-effects; however, this is controversial (9). It may be possible to ligate more than 1 sinus in dogs with an intracranial neoplastic lesion, as compression of the sinuses may lead to the development of collateral circulation, with no consequences with ligation of 2 or 3 of the sinuses (6). At this time, experiences with ligation of more than 1 sinus are anecdotal, with some reported successes and some dogs with neurologic consequences that lead to death.

The craniectomy may result in exposure of both the brain and the frontal sinus. This creates the potential for contamination and infection of the cranial vault. Perioperative antibiotics should be used with craniectomy and reconstruction techniques should focus on separating these 2 cavities if they are created. Porcine small intestinal submucosa and/or a temporalis muscle flap can be used to this end. Cranioplasty for reconstruction of the cranial vault to protect the brain has been reported in dogs using polymethyl methacrylate (PMMA) with a polypropelene mesh (10) and as a mold (11), titanium mesh (12), bone (13) and porcine small intestinal submucosal (PSIS) graft (14). In the case where a PSIS graft was used, it was thought to provide a scaffold for the development of new bone. In dogs, cranioplasty is generally not thought to be necessary if the defect is relatively small and the temporalis muscle can be brought over the defect (6). Cranioplasty should be considered with large defects; however, the major disadvantage of this technique is the potential for infection with a large implant at this site, especially if the frontal sinus is exposed. Advanced techniques such as rapid prototyping using CT scan have been reported in research dogs to develop a tailor-made tricalcium phosphate powder implant, with the goal of using these techniques in human craniectomy patients. The implants were found to be a safe and effective bone substitute with osteoconductive properties (15). This technology may have indications in veterinary medicine in the future. An external helmet can be made for the patient to protect the head when patients are outdoors.

Tumors of the orbit

The orbit is the bony cavity that surrounds and protects the eye. The bones that make up the orbit include the frontal, maxillary, lacrimal, and zygomatic bones. The orbital ligament between the frontal bone and zygomatic bone makes up the dorsolateral portion of the orbit. The soft tissue structures within the orbit include the globe, extraorbital muscles, lacrimal gland, cranial nerves, autonomic nerves, fat, arteries, veins, and smooth muscle. A thorough knowledge of the anatomy of the orbit is important prior to performing orbital surgery (16). The most common sign of orbital disease is displacement of the third eyelid and globe (16). Generally this displacement is exopthalmus with lateral, dorsal, or ventral displacement, depending on the location of the mass effect. This may be a subtle finding and the globe should be palpated for its ability to be retropulsed in the orbit. Enopthalmus is also possible if a neoplastic process causes lysis of the orbit or if the mass is rostral to the globe. Other clinical signs include chemosis, conjunctival erythema, periorbital swelling, pain on opening the mouth, neurological deficits (blindness), subretinal fluid accumulation, and posterior indentation of the globe (16).

When starting a diagnostic workup for orbital disease, neoplastic disease must be separated from non-neoplastic disease and surgical disease must be separated from nonsurgical disease. Orbital neoplasia can be classified as primary tumors arising from the orbital bone or soft-tissue structures within the orbit, or secondary tumors that are an extension of local neoplastic disease into the orbit. A large number of primary orbital tumors have been reported in dogs. Common tumors that have been reported include OSA, MLO, mast cell tumors, sarcomas, adenomas and adenocarcinomas, and primary optic nerve neoplasia (16,17). Primary orbital neoplasia is more common in dogs, whereas secondary orbital neoplasia is more common in cats. In cats, extension of squamous cell carcinoma (SCC) is the most common orbital neoplasm (18). Common non-neoplastic causes of orbital disease include orbital cellulitis or abscess and foreign body. Typically, orbital inflammation may be differentiated from neoplasia by a more painful and acute clinical course and a younger age of presentation (16). Neoplastic orbital disease is generally reported to have a more slowly progressive clinical course that is less painful on opening the mouth or on retropulsion of the globe (17). However, in a retrospective study of 44 dogs with orbital neoplasia Hendrix (19) noted that the distinction between neoplastic and non-neoplastic disease can be confounded by dogs with neoplastic disease presenting with an acute presentation, pain on opening the mouth, a purulent discharge on cytology and/or an initial response to a course of antibiotics.

Ultrasonography and skull radiography can be used as preliminary tools to evaluate orbital disease, but generally will not determine a definitive diagnosis (16). Skull radiography can be helpful in determining if there is bone lysis of the orbit or nasal cavity. Ultimately, 3-D imaging is necessary to determine the extent of disease and viability of surgical excision or radiation therapy. When the mass is completely retrobulbar, obtaining a tissue biopsy sample can be a challenge. Ultrasound may determine the presence of a mass or fluid cavity and can be used to guide a FNA for cytology or a Trucut biopsy needle into a mass (16,19). In 1 study, cytology from the orbital space was diagnostic in 49% of cases and non-surgical biopsies were diagnostic in 56% of cases. This study did not demonstrate that ultrasound guidance improved the diagnostic yield. Combining the results from FNA and non-surgical biopsy, the diagnostic yield in this study was 79% (19). This indicates that there will be a percentage of orbital masses that cannot be diagnosed with noninvasive cytology or biopsy techniques. These cases are very challenging because a relatively aggressive surgical approach may become necessary for a diagnosis. Although surgical biopsy has been reported at the time of enucleation, exenteration, orbitotomy, rhinotomy, and cytoreduction of the mass (17,19), this approach may confound definitive curative-intent surgery. A noninvasive approach with cytology and/or Trucut biopsy should be attempted first. If this fails to be diagnostic, advanced 3-D imaging should be performed to characterize the mass. The results of the advanced imaging will then determine if an incisional biopsy or excisional biopsy (definitive excision of the mass by exenteration or orbitectomy) is the next most appropriate step. An incisional biopsy should be performed with the definitive surgical resection in mind, noting that the biopsy tract will need to be resected and that fascial planes must not be disrupted beyond the planned definitive excision. An orbitotomy may be the most appropriate way to obtain an incisional biopsy if this is deemed necessary. As it becomes more readily available, stereotactic biopsy with CT guidance may prove to be a helpful technique to achieve a histologic diagnosis in these challenging cases. Nonsurgical diseases of the orbit include orbital cellulitis, retrobulbar lymphoma, and neoplastic processes that are too advanced for curative intent surgery. An example of this is neoplasia of the nasal cavity that has extended into the orbit.

Exenteration involves the removal of the globe and all of the soft tissue contents of the orbit. The plane of dissection is outside the extraocular muscles, rather than against the sclera as is performed with an enucleation (16). This technique is appropriate for neoplastic processes that are contained within the extraocular muscles. If the bony orbit is involved or if the tumor is growing against the bone such that the bone must be removed as a fascial plane deep to the tumor to achieve a curative resection, orbitectomy is necessary.

The decision to preserve the globe or not and whether or not to perform a partial or complete orbitectomy depends on the tumor type and the 3-D imaging. A partial orbitectomy is either a superior or inferior orbitectomy. A superior orbitectomy involves excision of the frontal bone, exposing the frontal sinus and nasal cavity. An inferior orbitectomy involves the resection of the zygomatic arch +/− portions of the maxilla. A complete orbitectomy combines these 2 procedures (20). With a partial orbitectomy for a neoplasm of the orbital bone that does not involve the globe or orbital contents, preservation of the globe may be possible.

The globe is sacrificed when a complete orbitectomy is required, the globe is involved in the neoplastic process, or the eyelids or other vital structures of the eye require removal (20). Careful thought regarding the ability to save the globe must be given. As a rule of thumb, if the soft tissue structures dorsal to the globe can be preserved, the globe can likely be preserved. For tumors involving the inferior orbit and maxilla, a combined dorsolateral and intraoral approach has been described to improve visualization and the access to this area. This approach involves a skin incision over the dorsolateral aspect of the nasal cavity and an intraoral incision in the buccal mucosa, just dorsal to the gingiva. A bipedicle flap of skin and buccal mucosa is thus created. The maxilla +/− medial orbit are removed en bloc by creating osteotomies in the dorsal and cranial maxilla first, then in the hard palate, with the final osteotomy in the caudal maxilla and medial orbit. This approach allows preservation of the globe (21).

Soft tissue sarcomas

Sarcomas such as hemangiopericytomas, fibrosarcomas, and soft tissue sarcomas can occur anywhere and can be seen overlying the orbit and skull. These masses require the same diagnostic plan as they would if found anywhere else on the body. An incisional biopsy for a histopathologic diagnosis and grading is necessary prior to definitive surgical correction. Staging should be performed to rule out metastatic disease. Advanced imaging such as CT or MRI should be performed to assess the extent of the tumor, whether or not there is bone invasion, and whether or not there is a fascial plane between the tumor and the calvarium. These tumors require true en bloc resection that includes the overlying skin and, often the calvarium. Surgical excision should be planned with 2- to 3-cm margins and 1 fascial plane deep to the tumor. Often this fascial plane is bone and a partial craniectomy or orbitectomy is required. If the upper eyelids, palpebral nerve, and third eyelid are removed in the en bloc resection, enucleation should be considered. If the lower eyelid is removed, it can be reconstructed using a lip-to-lid technique (22,23). In dogs with very pendulous lips, this technique can be considered when a portion of the upper eyelid is removed as well. However, either the third eyelid or the upper eyelid should be intact and functional to ensure the health of the globe. Wide excision of the soft tissues around the eye due to neoplasia may require reconstruction with a skin flap. The most useful flap for reconstruction in this area is the caudal auricular axial pattern flap. This flap has been reported in cases of orbitectomy (24).

Conclusion

Tumors of the cranium and orbit can be challenging. However, with an appropriate diagnostic workup that focuses on achieving a histologic diagnosis, staging and 3-D imaging, successful surgical management may be possible. Tumors of the calvarium such as MLO and OSA do not generally require removal of the overlying soft tissues. Tumors of the orbit vary greatly in origin and invasiveness, and partial or complete orbitectomy may be required. The decision to preserve the globe depends on the tumor origin and the degree of soft tissue involvement. Soft tissue sarcomas over the skull are treated like sarcomas found elsewhere in the body, with aggressive en bloc resection. Careful evaluation of the preoperative imaging, along with knowledge of the tumor biology, regional anatomy and strict adherence to principles of surgical oncology, will increase the probability of successful surgical management of these tumors.

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